Agricultural Anaerobic Digestion - Carbon Offset Evaluation
- Dairy Manure Digestion
- Co-digestion of dairy manure with other organics

This paper presents a draft assessment of the potential for meaningful carbon credits from anaerobic digestion of dairy manure and co-digestion of dairy manure combined with other organic sources. Much of this paper directly presents the work and analysis of Frear, et al., (2008) of Washington State University Department of Biological Systems Engineering, and Department of Biosystems and Agricultural Engineering, Michigan State University, and Liao, Frear and Chen (2007).

Industry Background

An estimated 8% of all US anthropogenic methane emissions results from animal manure management with dairy manure representing 43.3% of the total. Dairy manure methane emissions have risen by approximately 50% between the years 1990 and 2005 primarily because the industry has moved during that time towards more concentrated animal feeding operations (CAFO) that utilize liquid manure handling systems that are more susceptible to anaerobic conditions and therefore methane release (US EPA, 2007).

The dairy industry in Washington consists of approximately 250-300 dairies with about 250,000 annual average milking cows. Dairy manure typically is managed through either flush or scrape systems. Flush systems produce a dilute liquid consisting of about 0.5 to 2 percent solids. Scrape systems typically produce up to 10% solids. Effluent from flush systems is stored in lagoons awaiting land application under a Dairy Nutrient Management Plan. Scrape systems are managed in piles or pits and may be direct land applied for fertilizer value on crop land, or composted to be sold as a soil amendment. Dairy in Washington produces about 450,000 dry tons of manure annually.

Washington State University has identified typical parameters for dairy manure on page 15 and 16 in the report, Biomass Inventory Technology and Economics Assessment, Characteristics of Biomass, 2007 (Liao, Frear and Chen). Liao, Frear and Chen found that, “dairy manure is rich in cellulose, hemicellulose, and proteins which is a potential raw material for commercial bioethanol production, gasification, and anaerobic digestion.“ The parameters of typical dairy manure are included in pages attached to this evaluation.

Analysis of the operation at a Lynden Washington digester including co-digestion and combined heat and power (CHP) production has the potential for reducing greenhouse gas emissions via three distinct avenues:

- manure methane capture and conversion as calculated against an assumed baseline liquid manure management,

- Organic municipal solid waste methane capture and conversion as calculated against an assumed baseline landfill management, and
- fossil fuel emission offsets from use of the biogas in CHP renewable energy.

Digestion of Dairy Manure and Co-digestion of Organic materials

A US specific methodology has been developed by the US EPA to develop methane conversion factors (MCF) for lagoon and liquid manure handling systems so that a baseline can be made in regard to methane mitigation. In short, the methodology considers the effects of (1) volatile solids (VS) available in the manure, (2) ambient lagoon temperature on microbial conversion kinetics, (3) management and design factors such as course solids removal, and (4) VS carry over during long-term storage to calculate a MCF for particular baseline manure management systems within specific climate locations (US EPA, 2007). The resulting calculation for the Lynden WA system utilizing manure from 1190 AU produces a methane emissions baseline of 405,615 kg CH_4/yr or 2.323 kilotons of C-equivalents/yr. The baseline emission value calculated above can be used to determine the carbon credits that a farm can receive for the AD processing of their manure. For purposes of this report a 2008 average trade value of $5.65/metric ton CO_2 equivalent with a 50% trade commission was used to calculate the number of credits and credit value received for the Lynden WA AD project (CCX, 2008). Revenues from the manure methane carbon credits could then be $24,063/yr.

The Lynden WA dairy is co-digesting its manure with organic municipal solid waste substrates. Just as in the case of manure where the AD treatment is set against a baseline liquid manure management system, the organic municipal solid waste digestion can be set against an assumed baseline represented by landfill treatment. A baseline emission value for the flow of organic municipal solid waste substrates into the Lynden WA digester can be determined using assumptions noted by Murphy and McKeogh (2004), namely that long-term anaerobic digestion of organic municipal solid waste in a landfill results in a maximum of 65% VS destruction, 1 m^3 of biogas per kg VS destroyed, 55.5% methane content in biogas, and 0.396 kg CH_4/m^3 biogas produced. The resulting calculation shows baseline emissions of 323,991 kg CH_4/yr or 1.856 kilotons of C-equivalents/yr. Using an assumed similar revenue trade model as performed with the manure methane carbon credits, the organic municipal solid waste carbon credits could be worth $19,221/yr.

Beyond the carbon credits and potential revenue generated from the above methane baseline calculations there is the potential for additional greenhouse gas offsets and revenues based upon fossil fuel offsets through the use of the biogas in combined heat and power operations. The Chicago Climate Exchange calculates their energy offsets at a rate of 0.4 metric tons of CO_2-equivalents/MWh electricity generated (CCX, 2008). This means that given the mean biogas production and the CAT G398 engine specifications, the Lynden WA digester can produce, at 90% running time, 2,787 MWh a year or offset 0.304 kilotons of C-equivalents/yr. At the same revenue rate as calculated above, this could translate into revenue of $3,149/yr.

Overall Policy Issues

There are several issues that must be addressed in order to develop a carbon trading contract for anaerobic digester in agriculture.

- Digesters must demonstrate for comparison where the manure or other digested materials would have gone other than digestion. Standard comparisons for dairy manure, and other organic sources must be established including carbon footprint of the alternative management strategy.
- Records of the type and source of digested materials must be maintained. Measurements of the mass of the digester inputs and outflows must be kept.
- Gas production data, electricity production, power sales or fuels substituted must be kept to demonstrate the carbon offset value.
- Performance or production of methane and nitrogen recovered beyond dairy production levels.
- Adherence to a Dairy Nutrient Management Plan.

Technical Issues

Baseline dairy digestion will vary with the type of digestion system and other parameters including local climate, digester temperature range, residence time, etc. It is well understood that gas production from dairy manure digestion can be dramatically improved with co-digestion of as little as 10%-15% additional mass of other organics typically from food processors, slaughter houses, fisheries, etc. These added materials provide high volatile solids (VS) concentrations that consist of carbohydrates, lipids, and proteins. Microbial breakdown of these added materials significantly improves methane gas production. In some cases, the production of methane is greater than one would predict from model evaluations of the added VS. This synergistic production is the results of the combined materials sources creating higher level optimum conditions that result in greater gas production than separate digestion alone.

Because of the variability of organic sources, climate, and type and temperature of digester, carbon offsets should be provided based on comparison to standard lagoon or landfill management practices with actual production data from the facility. Digesters, particularly the generator set for clean heat and power production require regular maintenance, and operations support. Standard equipment on a digester typically would include gas production measurement and power production information. These provide specific data for establishing the carbon offsets.

WSU has pointed out that current carbon contracts on digesters only provide payment for methane capture avoidance from the manure digestion. The carbon trading platform established in Washington and western states should support methane offset credits regardless of source of the organics based on simple comparative data for comparing passed manure management practices which are largely lagoon systems for dairy operations. An analysis of alternative practices for manure management may be needed to assess other baselines than the lagoon system. For other organics from municipal sold wastes, the baseline should be considered landfill management.

Specific Policy Considerations

Several issues must be considered in developing carbon offset policy for digesters. First, carbon offsets should be compared to a standard set of current management strategies. Second, carbon offsets should be available for all sources of digested materials. Current markets provide limited production offsets for only dairy digestion. Numerous opportunities exist across the state both on and off farm for development for non-manure digesters. Third, the development of digester will allow for fossil fuel offsets in power production, and in transportation or on farm fuel consumption. The benefits of these substitute fuels should be considered for offset. This issue deserves high consideration and the development of better discussion than time allows currently.

Other questions that may be considered in the development of carbon offsets may include:

- Should nutrient recovery (ammonia N) be considered as a BMP, or direct offset?
- Should we have a nitrogen fertilizer background capture discussion or defer until the technology becomes available?
- Should we allow offsets for methane use as a fertilizer input (substitute source of natural gas for industrial production of ammonia through the Haber process)?
- Should we also consider the use of on-farm methane as a substitute for diesel in transportation fuels either on the farm or in off-farm process?

Baselines and models

Good baseline data on the characteristic parameters of dairy manure exist with which to assess dairy anaerobic digestion and methane recovery. With the development of the Characteristics of Biomass report and the research background and numerous papers from WSU research and extension staff on anaerobic digestion, a fairly comprehensive data base has been developed for flush dairy operations. Applicable characteristic data are also available for typical scrape dairy systems.

Dairy manure characteristics determined from laboratory analysis provide inputs to software applications that are used to predict a range of digester methane production outcomes. These models of the anaerobic digestion of manure have been developed such that values for carbon offsets can be predicted given standard chemical analysis inputs.

In addition, characteristic parameters for a variety of co-digestion materials have also been evaluated and presented by Liao, Frear and Chen (2007). What is of more value is that the useful analytical parameters for a waste stream have been identified. Therefore, for any particular material, a laboratory analysis can be done to assess co-digestion.

Need for Data Development

As digesters come on line, basic data are required to demonstrate the carbon offset values from the digester. These should include the following:

- Daily materials input of manure and other organics.
- Facility operations data such as temperature profile, daily inputs and outputs, sources of materials and materials type.
- Gas production data.
- Generated power in Mwhr.
- Alternative fuels production to offset diesel usage.